TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 273

THE EFFECT ON PERFORMANCE OF A CUTAWAY CENTER SECTION

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Summary

The assumption is made that a skeleton or cutaway center section is desirable for forward vision and to determine the effect of such mutilation upon performance the following work was done.

The airplane used was a Vought VE-7 and in addition to the cutaway center section a system of end plates or fins was installed. Various conditions and combinations were investigated in level flight and in climb.

It is found that the greatest difference in the conditions investigated was a drop of 12.5 per cent in a 10-minute climb while the effect upon level speeds was negligible.

It is, we believe, properly assumed that most military aircraft are deficient in forward vision. This deficiency is largely attributed to the interference of the center section and is of the greatest consequence in the tactical maneuvers of diving upon an objective or of following an aerial objective, on a circular path. That an improvement is possible by removing the

covering of the center section has been appreciated for a long time, it being quite the common practice in British squadrons during the late war to make such alterations in the field, particularly upon pursuit airplanes of the Sopwith Camel and other types. In addition to this makeshift expedient the modification has been considered, and built into some experimental types but it has always been considered that the improvement in visibility has been obtained at too great an aerodynamic cost.

Considerable information in regard to this loss is at hand and a curve which has been taken from a German report, "Technische Berichte," 1917-1918, Vol. I, is given herewith (Figure 5). It has been believed that these modifications have been less artfully accomplished in the experimental form than is readily practicable, that is, the openings in the center section have more usually been considered as straight slots cut through the center section of the wing or simple holes of varying forms cut out of the center section.

The differences between model investigation and this full scale work can be conjecturally contributed to the fact that in the model investigation the effects of the slip stream are absent, the losses due to tips in the airfoil being largely due to the formation of eddies. It is surmised that these eddies are destroyed or lost in the larger eddy of the slip stream with the consequent difference in the aerodynamic loss.

For this work a Vought VE-7 airplane was selected and although the visibility of the type is not bad the improvement in the range of vision is nevertheless considerable. The effect of the mutilation upon performance as a practical evaluation of the aerodynamic deficiency of the modification is determined by simple flight tests comprising only level flights at a low altitude at varying engine speeds and climbs of 10 minutes duration at an optimum air speed.

The flight results were taken with the N.A.C.A. recording air-speed meter and the recording altimeter.

The gross weight of the airplane was maintained constant throughout the tests and the flights being conducted within a very short period the power of the engine is assumed also to be constant. Barometric pressures were the same for all flights within very small limits which can be considered as having no effect upon the recorded performances. Six conditions were investigated, the first of which may be considered the zero condition consisting in filling in the trailing edge cut-out of the center section which is normal to the type, this giving continuous chord and profile (Figure 8). The second condition was the normal cut-out of the trailing edge only (Figure 9). The other four conditions were based on a special center section which was designed to give a maximum visibility and consisted in skeletonizing the center section as is best illustrated by the photographs included with this report. This consisted in two special spars of

tubular steel construction which were streamlined and with the lifting surface partially filled in with a surface which followed the usually accepted wing tip practice substantially semi-elliptical in plan form and tapered in thickness (Figure 10). The width of the opening was intentionally made much greater than would be required in practice and the improved range of vision while largely one of quality can be partially appreciated by the demands of the improved angles of vision which are given.

The loss in aerodynamic efficiency is obviously less due to the loss of the lifting surface than to the inclusion of what may be considered two additional wing ends in the cellule which with their usual tip losses are the more accountable. In order to maintain straight flow over these portions of the wings and thereby to prevent the usual tip losses, end plates or fins according to the system suggested by Mr. E. G. Reid in N.A.C.A. Report No. 201 were installed in various combinations. These fins were laid out for the particular purpose by Mr. Reid to give the maximum shielding effect. These are considerably larger than would be suggested for service use.

The remaining four conditions of structure were with the cutaway center section with both top and bottom fins on, (Figure 11); with top fins only, (Figure 12); with lower fins only, (Figure 13); and last, the cutaway center section alone without the fins (Figure 10).

With various combinations of these modifications the airplane

was kept in regular miscellaneous service for some time and was flown by a number of pilots who were familiar with the airplane. The effect of the modification had no qualitative effect upon performance which could be determined by any of the pilots who flew the airplane with the single and very minor exception of a slight difference in the landing characteristics which manifested itself at the instant that the airplane settled upon the ground. This difference was commented upon many times and checked but could be considered as neither better nor worse but merely different. To describe this rather fleeting phenomena is somewhat difficult, but it might be stated that the airplane in landing showed no difference in characteristic up to the instant when it settled upon the ground, excepting that at this instant the movement was a little more decisive and abrupt than usual.

The performance in level flight was obtained by flying a course at an altitude of approximately 100 feet, i.e., well above any ground effect, at a number of air speeds with a range of engine speeds from 1200 to 1740 R.P.M. Figure 1 is a composite plotting of these six curves and shows a maximum difference in speed of $2\frac{1}{2}$ miles per hour under all conditions. As might be expected No. 1 condition, continuous chord center section, gave the best high speed performance while the other conditions are so close together that an evaluation of their low incidence characteristics is difficult. The maximum difference of $2\frac{1}{2}$ miles per hour is considered as being well within the experimental er-

ror in making tests of this character and therefore the speed performances under both conditions may be considered as being the same.

The performances in climb were investigated under the condition of a constant indicated speed climb for 10 minutes as a criterion. Figures 2, 3, and 4 give the climb for the six conditions at air speeds at 60, at 70, and at 80 miles per hour constant indicated speed from which it is evident that the optimum rate of climb is at or near 70 miles per hour for all conditions of center section structure.

At 70 miles per hour the No. 1 condition again shows the best with the normal trailing edge cut-out center section, condition No. 2 having a $2\frac{1}{2}$ per cent loss. The No. 5 condition, that is, the cutaway center section with lower fins only had a 5 per cent loss over the zero condition, and the poorest condition, which was No. 6, the cutaway center section without fins shows a loss of $12\frac{1}{2}$ per cent.

The improvement of visibility can only be qualitatively evaluated and it is considered by all who have flown the airplane, to be a very extensive improvement. The installation of the fins, particularly those on the lower side, is of some impairment to the vision but still considerably less so than the normal or full center section.

The diagram included herewith attempts to show in a qualitative way what the improvement in vision is on the VE-7 and what

it might be on a pursuit type (Figures 6 and 7). The final conclusions must be reached in an experimental design on a pursuit type and the experiment is very earnestly recommended by the many service pilots who have flown or inspected the modification.

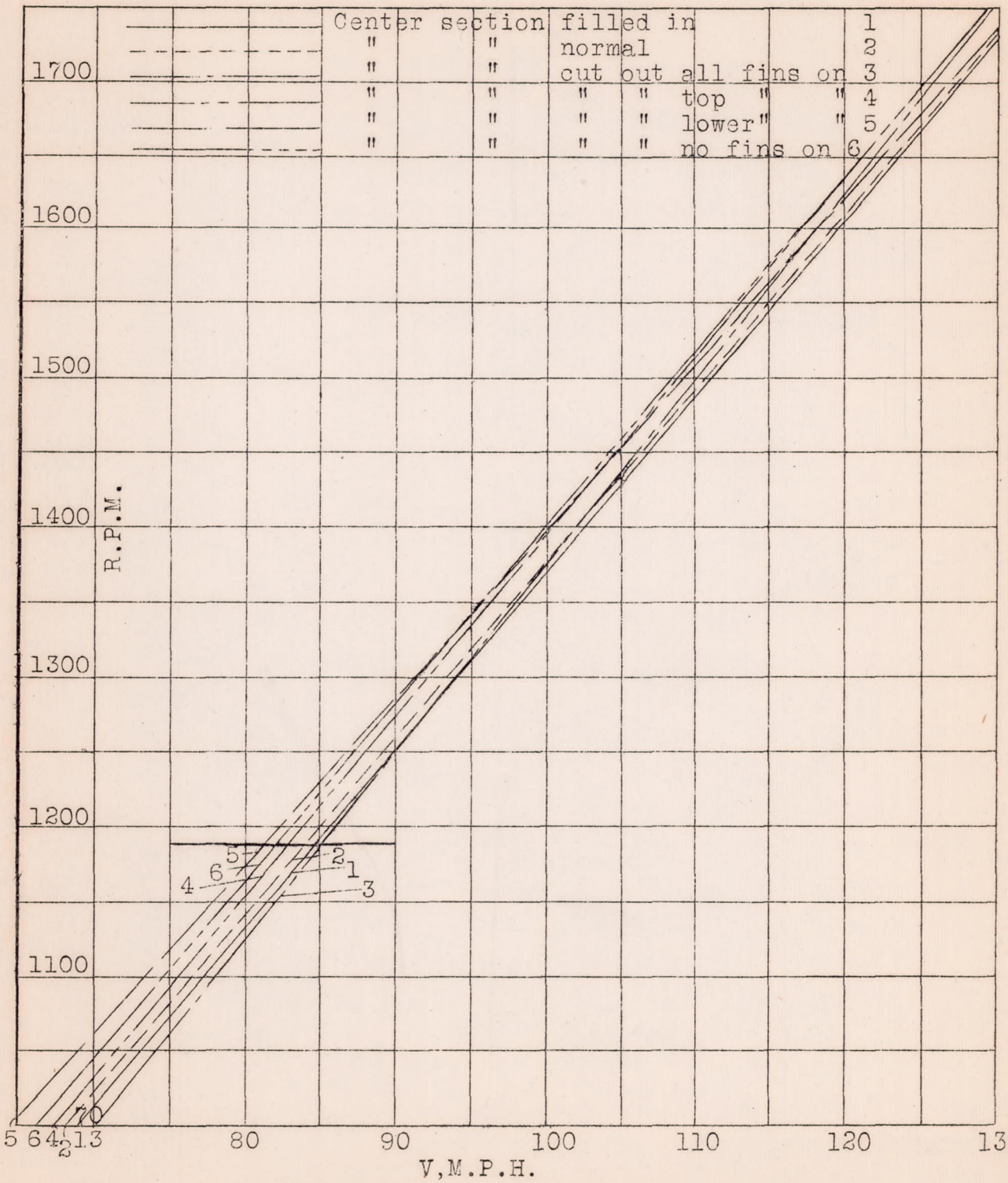

Center section filled in 1
" " normal 2
" " cut out all fins on 3
" " " " top " " 4
" " " " lower" " 5
" " " " no fins on 6
1700
1600
1500
1400
1300
1200
1100
R.P.M.
5 6 4 2 1 3
4 6 5 2 1 3
80
90
100
110
120
130
V,M.P.H.

Fig.1

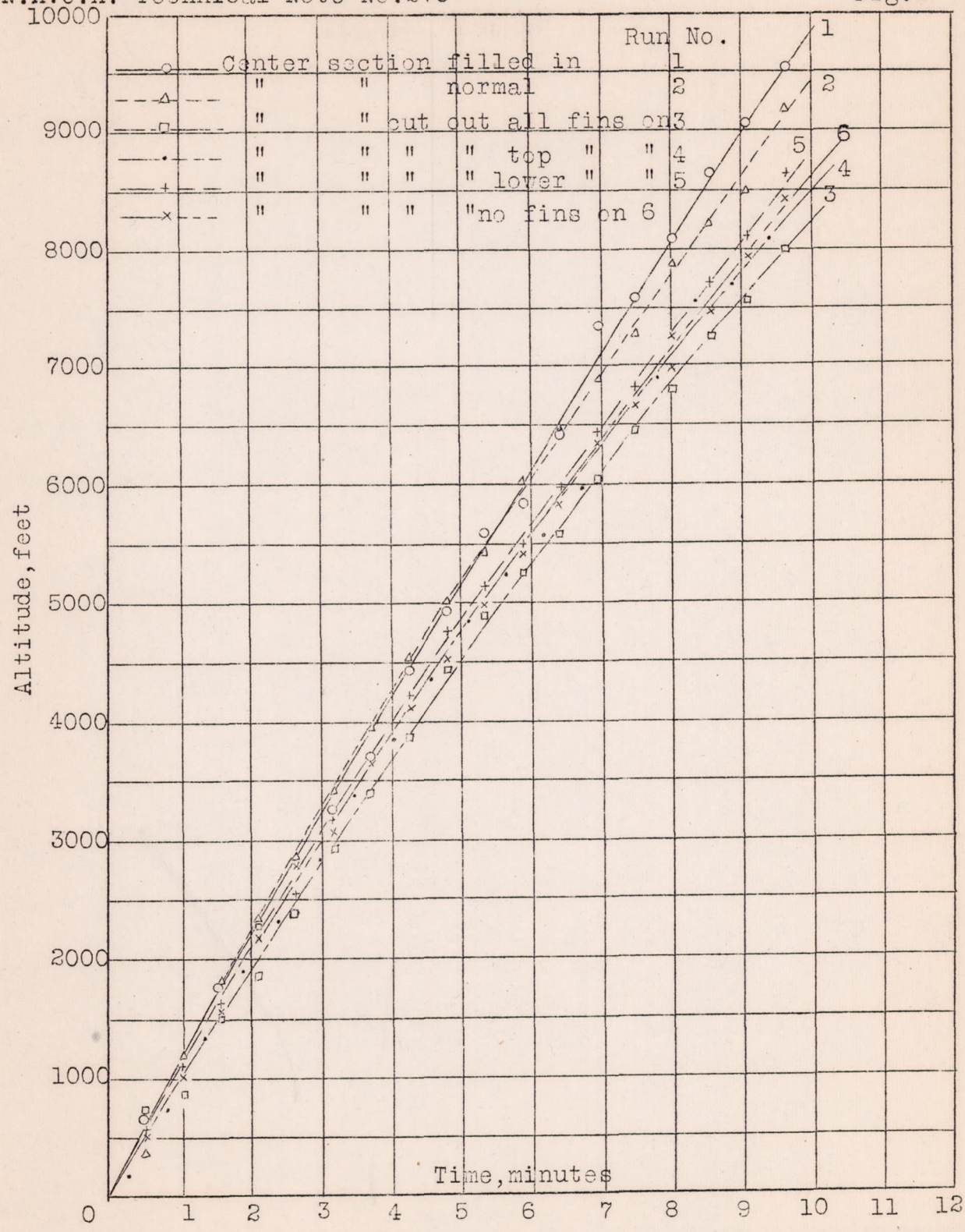

Run No.
Center section filled in 1
" " normal 2
" " cut out all fins on 3
" " " " top " " 4
" " " " lower " " 5
" " " "no fins on 6
Altitude, feet
Time, minutes
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1
2
3
4
5
6
7
8
9
10
11
12

Fig.2 60 M.P.H.

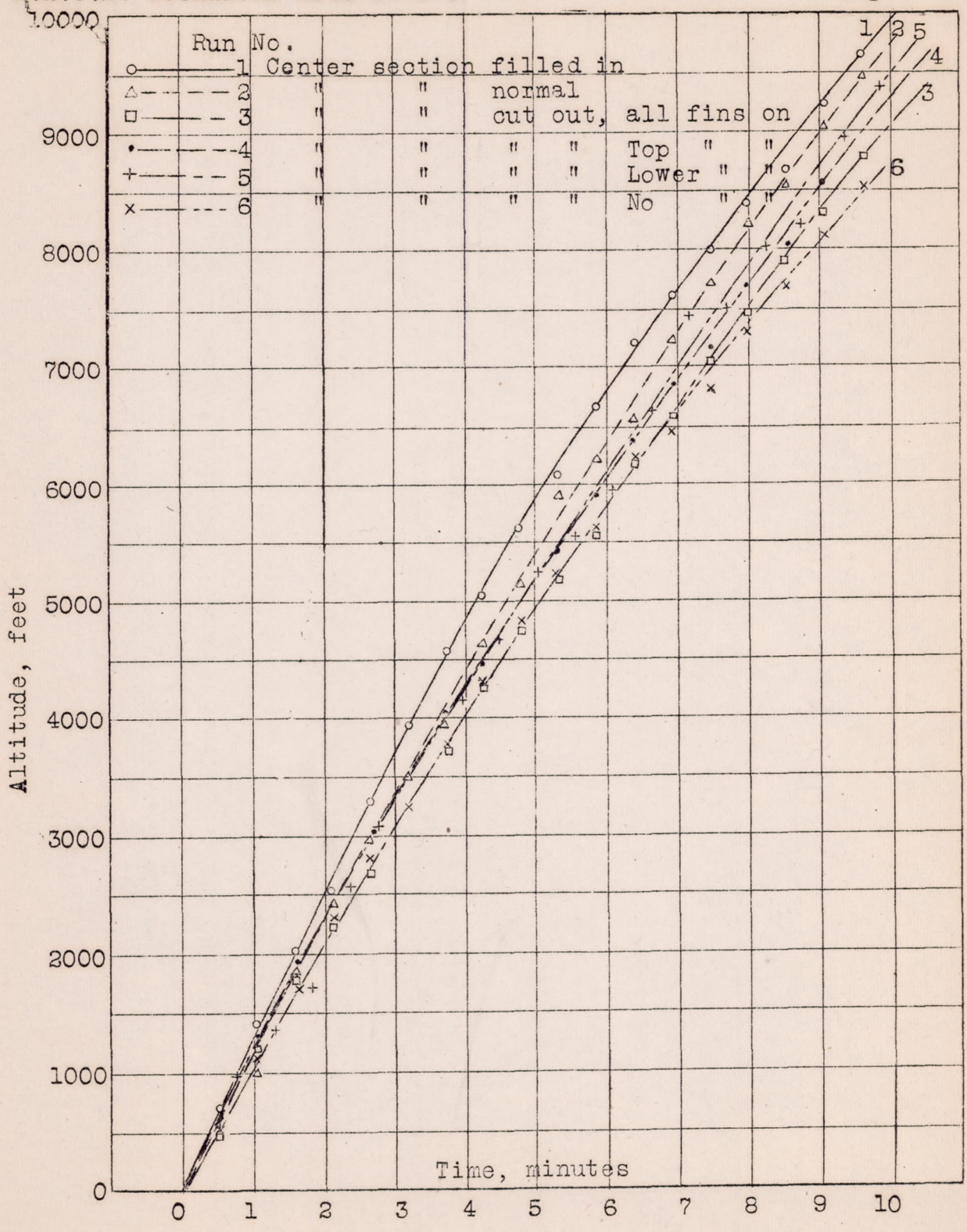

Run No.
1 Center section filled in normal
2 " " cut out, all fins on
3 " " " " Top " "
4 " " " " Lower " "
5 " " " " No " "
6
Altitude, feet
Time, minutes
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
0 1 2 3 4 5 6 7 8 9 10

Fig.3 70 M.P.H.

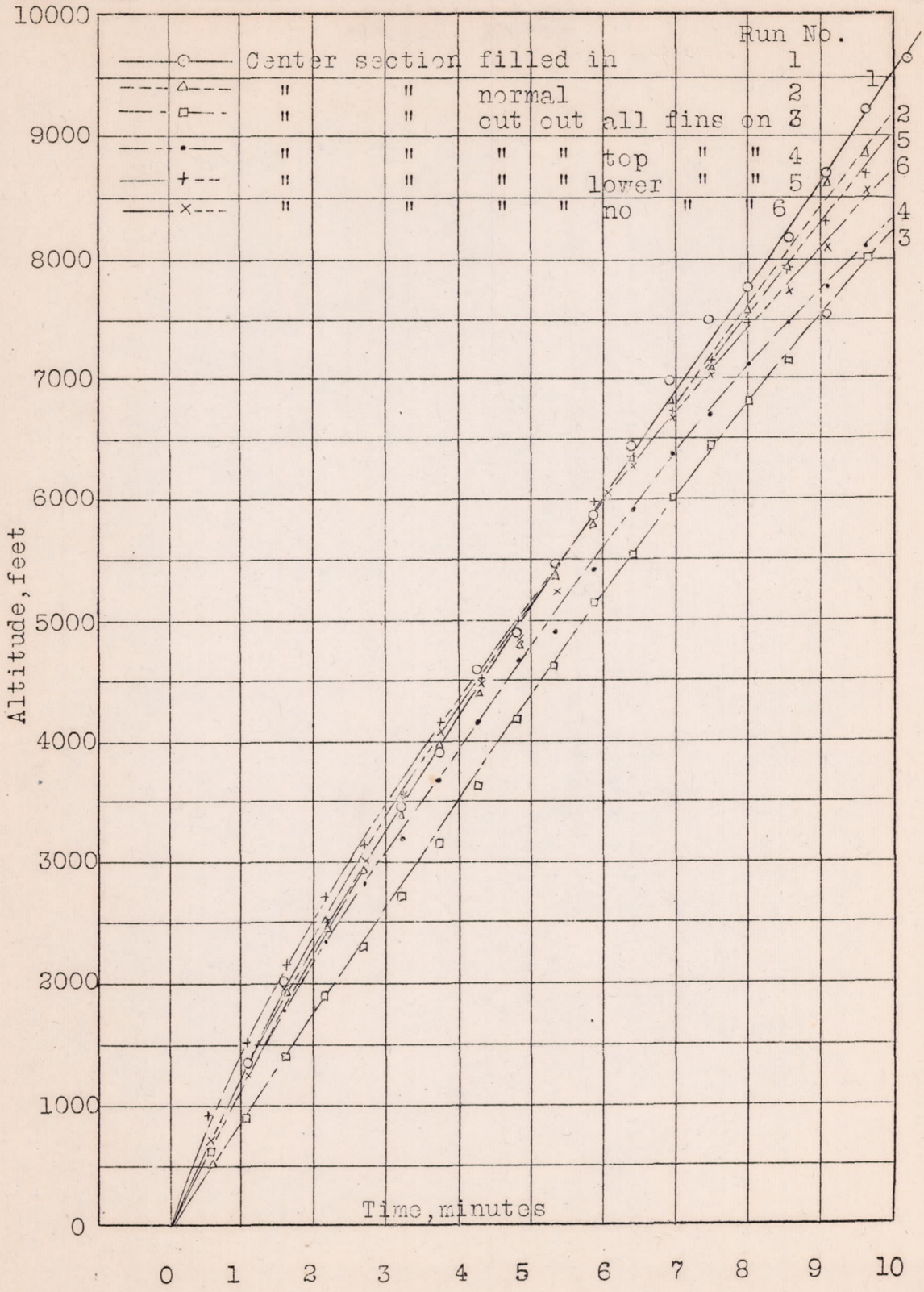

Run No.
Center section filled in 1
" " normal 2
" " cut out all fins on 3
" " " " top " " 4
" " " " lower " " 5
" " " " no " " 6
Altitude, feet
Time, minutes
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0 1 2 3 4 5 6 7 8 9 10

Fig.4 80 M.P.H.

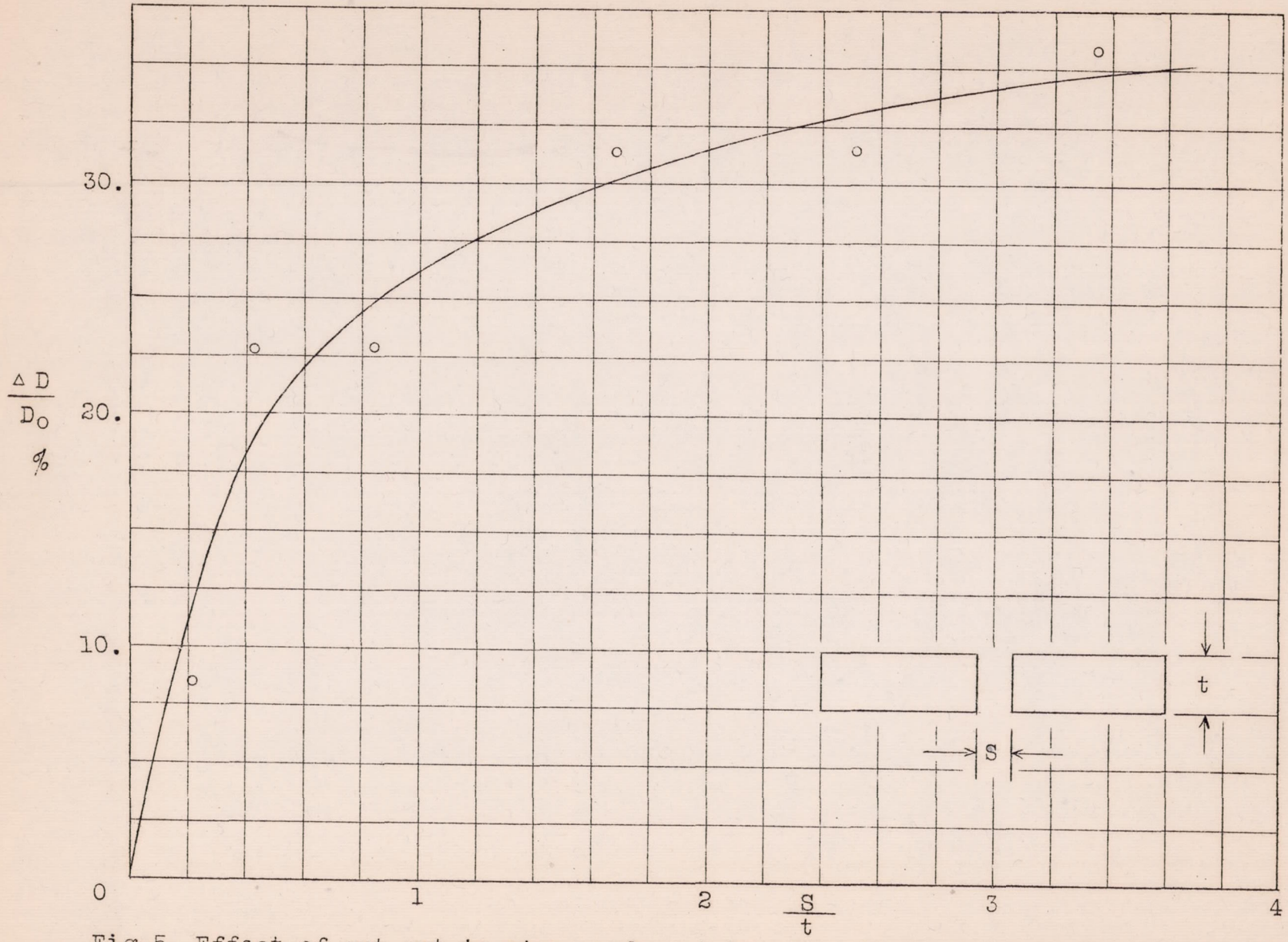


Fig.5 Effect of cut out in wing on drag taken from Tech. Br. 1917 Vol.I, page 219
Range of angle of attack 6°-9°.

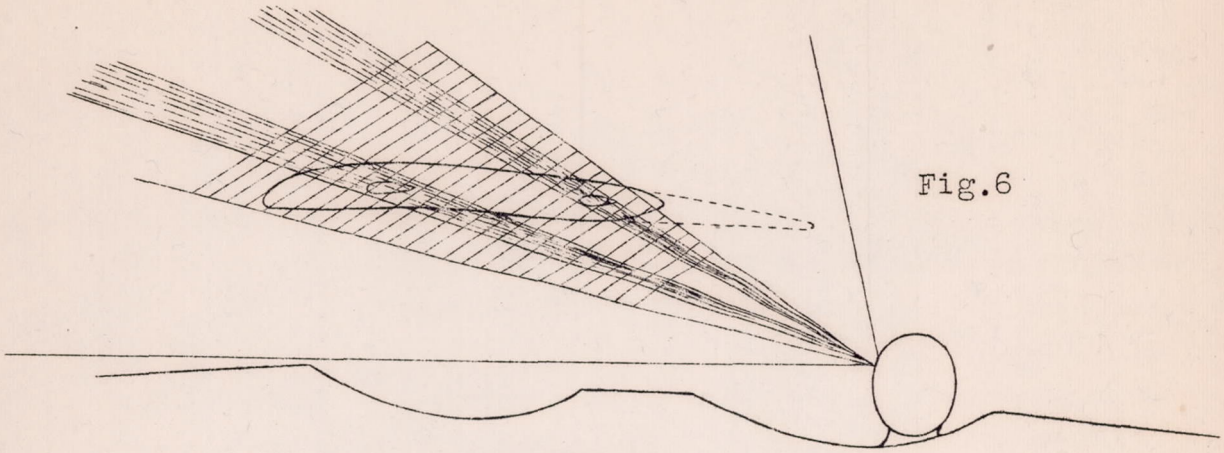


Fig.6

The Vought VE-7

Diagrams illustrating the reduction of blind angles of forward vision with normal and cutaway center sections.

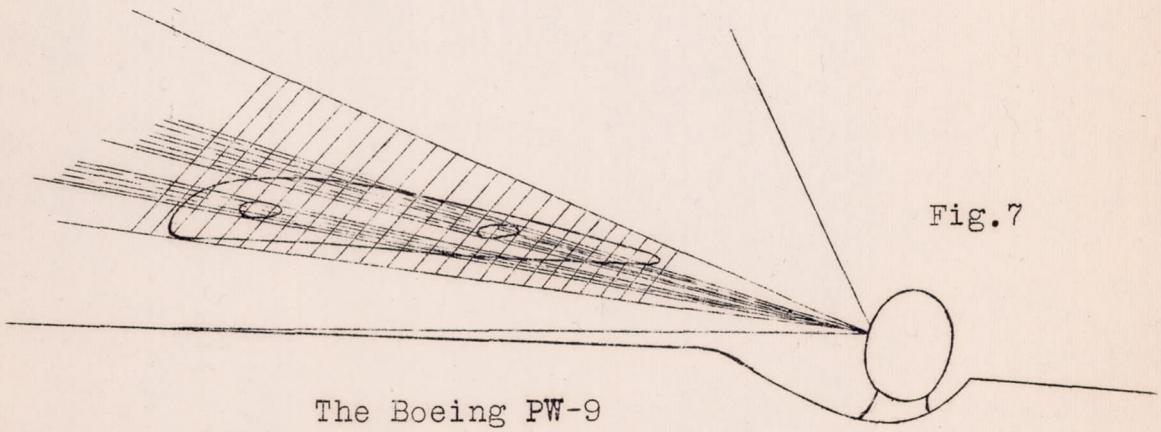
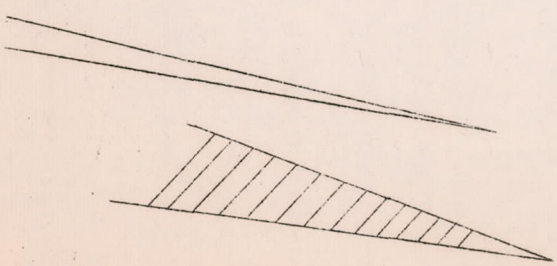


Fig.7

The Boeing PW-9



Field of vision blinded by cutaway center section.

Field of vision blinded by normal center section.

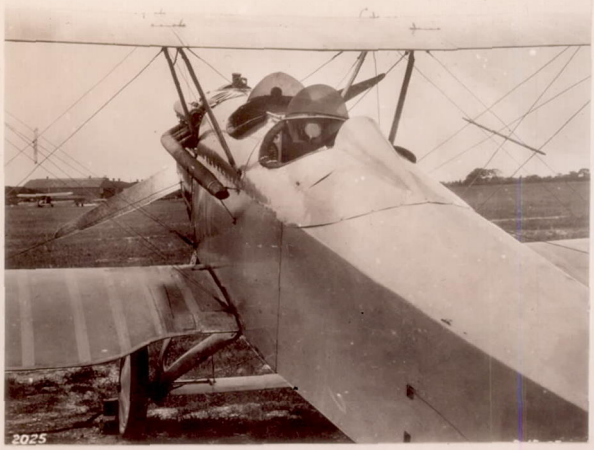


Fig.8 Trailing edge filled in.

Fig.10 Cut-out without fins.

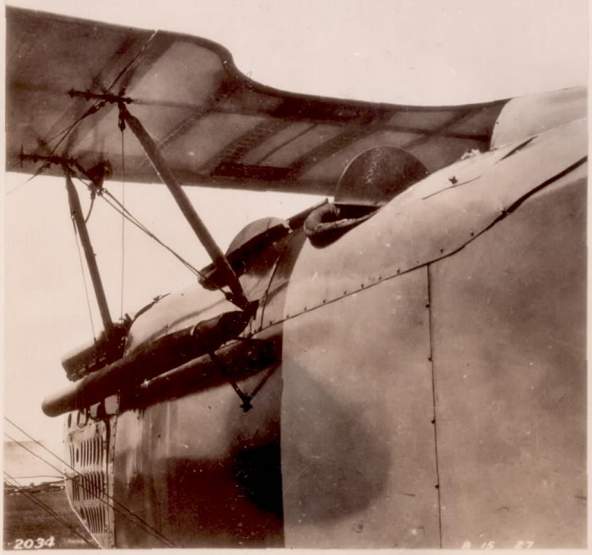


Fig.9 Normal trailing edge.

Fig.11 With top and bottom fins.

Fig.12 With top fins only.

Fig.13 With bottom fins only.